Selection of TFF Cassette Feed Screen for Efficiency

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Introduction

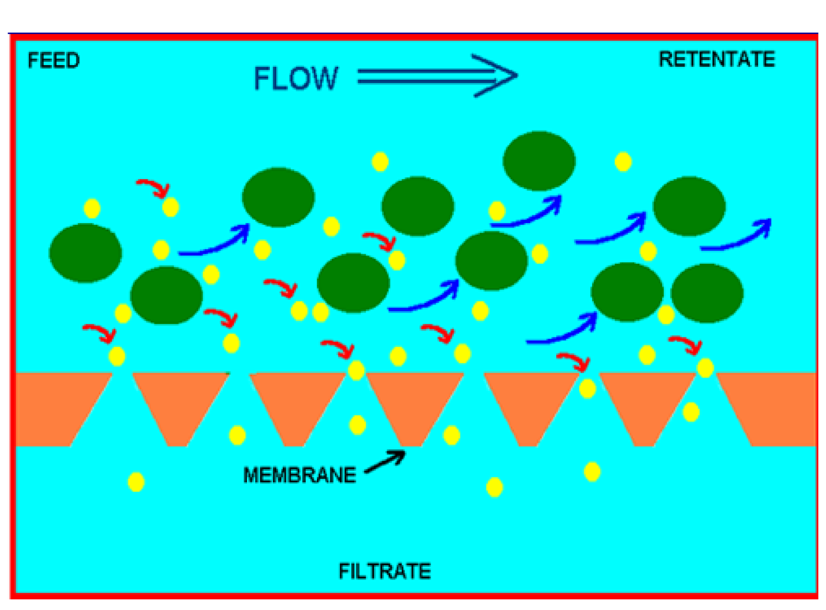
Repligen TangenX® Tangential Flow Filtration (TFF) Flat Sheet Cassettes current portfolio include several different feed channel geometries that influence hydrodynamic flow characteristics. These hydrodynamic characteristics have a direct impact to processing performance of the cassettes. The feed channel configuration is determined by the screens used within TFF cassettes, which are important to generate turbulence or "sweeping" of the membrane surface, preventing fouling and reducing the gel layer for efficient process flux. The feed channel path length, height, and screen weave contribute to the performance of the cassette. All the screens within Repligen's TFF cassettes meet USP Class IV Standards, BPOG compliant, melamine and BSE/TSE Free, latex free, and FDA approved.

The screens' geometry varies in thickness and open area to manipulate crossflow and pressure drop within cassettes. A thicker and more open screen will reduce pressure drop and increase crossflow, while a tighter, thinner screen will lower the crossflow and increase pressure drop. The current channel offerings with Repligen TFF cassettes are outlined in **the Table below**.

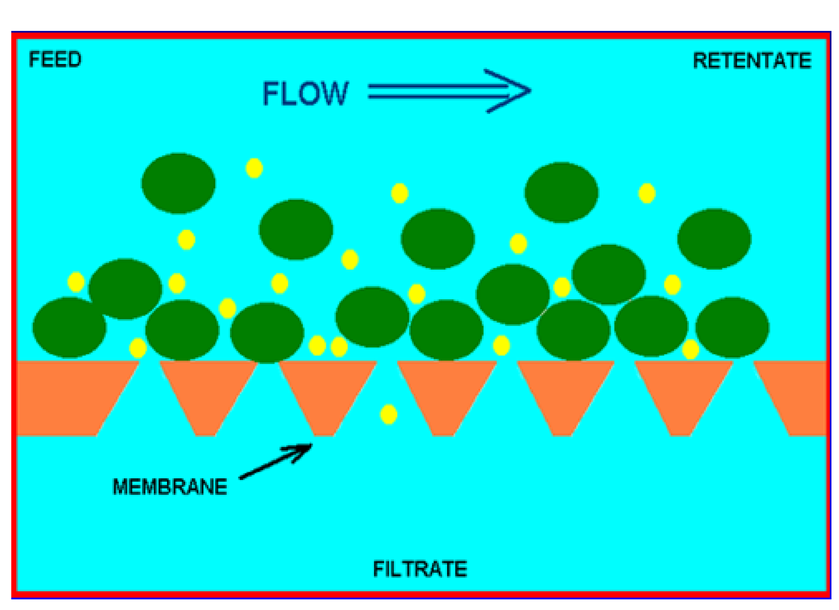
Channel Configuration	Product Line Offerings	Pressure Drop (with Water)	Crossflow (L/min/m²)
'L' Channel (Low Pressure)	SIUS, PRO, SIUS Gamma, SC	10 psi (0.7 bar)	4 – 8
'H' Channel (High Pressure)	PRO	15 psi (1 bar)	4 – 8
'E' Channel (Extra Low Pressure)	SIUS, PRO, SIUS Gamma	5 psi (0.35 bar)	6 – 12
'S' Channel (Suspended Channel)	PRO	1.5 psi (0.1 bar)	9 – 15
'J' Channel (Open Channel)	SIUS	<1 psi (<0.07 bar)	10 – 15

What is Screen Efficiency?

Screen efficiency can be defined as a screen that optimizes the relationship between operating costs and membrane productivity. Membrane productivity or permeate flux is the result from the mass transfer within a cassette. In TFF, mass transfer can be defined as the ratio between the flux and the resistance at the membrane surface. In ultrafiltration (UF) based applications, the resistance is the difference of the solute concentration between the membrane surface concentration (gel layer) and the feed stream concentration. The greater the resistance, the larger hydrodynamic driving force (transmembrane pressure) is needed to generate the optimal flux. Membrane area, crossflow, pressure, turbulence, and transmembrane pressure, and viscosity will impact the effective mass transfer within a cassette.



Optimized Membrane = High Product Recovery



Fouled Membrane = Low Product Recovery

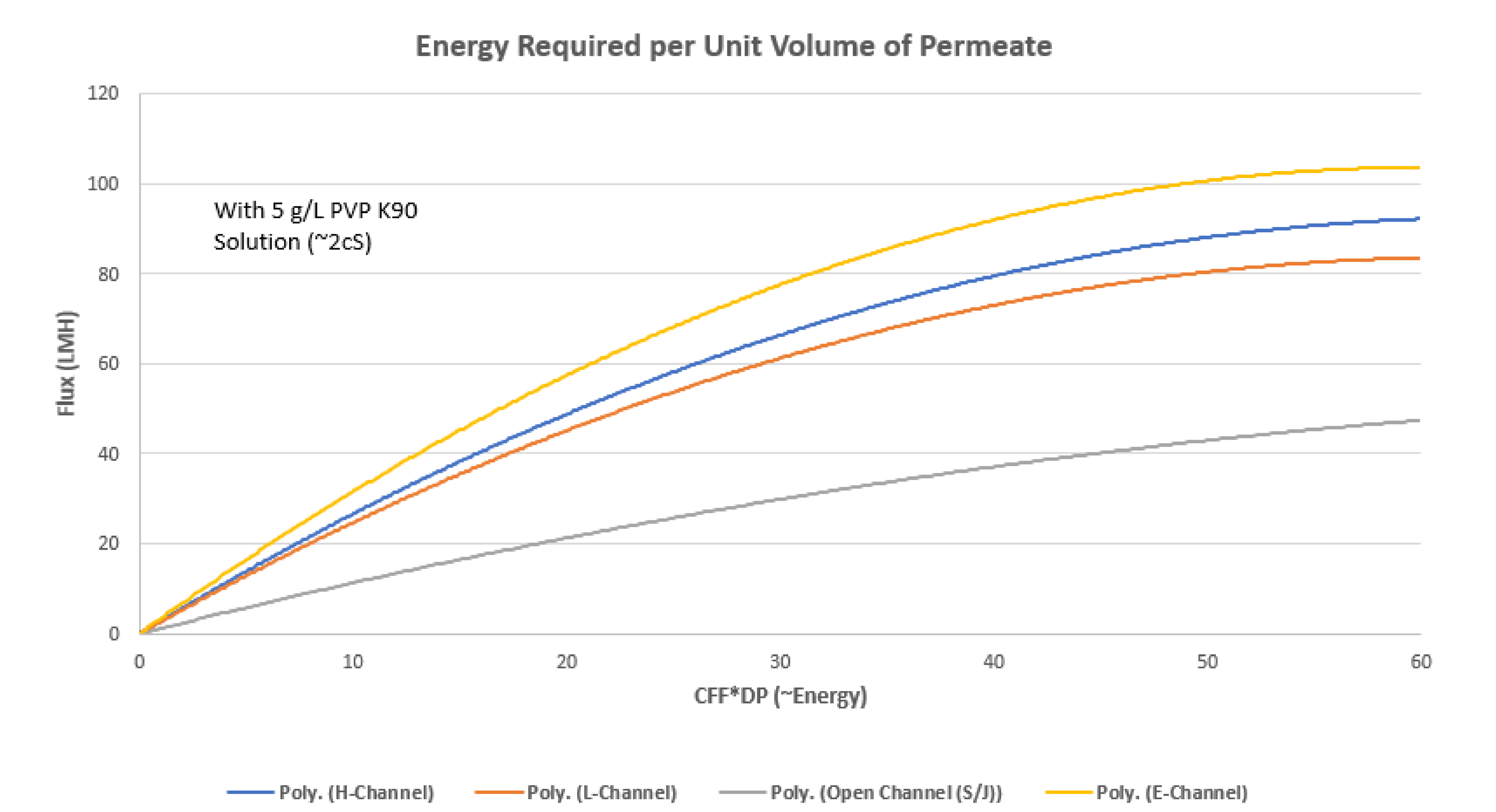
What affects Mass Transfer?

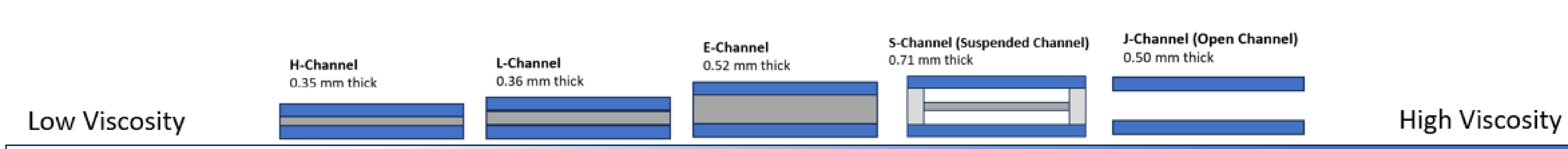
- Turbulence or "sweeping" of the membrane surface is the main counter force in reducing the concentration polarization of the solute at the membrane surface. Within TFF cassettes, screens are used as turbulence promotors to minimize concentration polarization. With adequate turbulence, the gel layer will be disturbed, decreasing the gel layer resistance to increase permeate flux.
- Transmembrane pressure (TMP) is a driving force against the resistance of the gel layer, that when optimized, can generate high flux and lower processing times. Too much TMP, however, will increase the gel layer formation, reducing flux.
- Pressure drop (DP) is a negative effect on the mass transfer as it affects the TMP across the membrane surface. A large pressure drop can increase the TMP at the feed ports and drive the gel layer up at the ports, lowering the flux and reducing the active surface area for filtration. Pressure drop is manipulated with the crossflow and the channel height (screen height). The larger the pressure drop, the larger the resistance from the increased gel layer and lower flux.
- Viscosity of the feed stream will affect the mass transfer as it affects pressure. Increased viscosity increases the pressure within the system and will in turn increase the gel layer. With increased viscosity, lowering the crossflow to reduce pressure will help, but will reduce the turbulence at the surface, promoting gel layer build up and in turn lower the flux. If we increase the screen thickness/channel height, we can reduce the pressure drop, increase the crossflow and can generate higher flux. Therefore, a thicker screen will be optimal for increased viscous solutions. A thinner screen will be unusable with higher viscosities as the pressure drop will be unacceptable and unachievable. Both TMP and Δ P will impact the driving force affecting mass transfer.

Low Energy + High Mass Transfer = Lower Costs

Pressure drop is a substantial force in the cost per unit volume of permeate as higher pumping rates will be needed to achieve higher pressure drops. The cost to run such pumps can be strenuous and pivots the selection process more to a consideration of energy used per unit volume of permeate. The more energy expended in the process, the more costly, but the less energy used will be more cost efficient. Increased energy consumption in cassettes is directly related to the pressure drop lost within the cassette. Total pump energy can be calculated as the inputted energy (crossflow) multiplied by the energy lost (pressure drop). The energy can then be compared to the permeate flux or the total mass transfer to determine the energy consumption per unit volume of permeate. A screen type that had a low energy cost per unit of permeate will be the most efficient.

Experimental testing was conducted to determine the screen efficiency of Repligen TangenX Cassettes. A 5g/L water-soluble polymer, polyvinylpyrrolidone (PVP), was used to replicate a generic feed stream. The PVP solution was recirculated through 30kD ProStream cassettes at various pressure drops, crossflows, and transmembrane pressures to monitor the permeate flux of each screen configuration offered at Repligen. For the bottom figure, 10g/L IgG solution was concentrated to generate viscosity vs pressure drop curve.





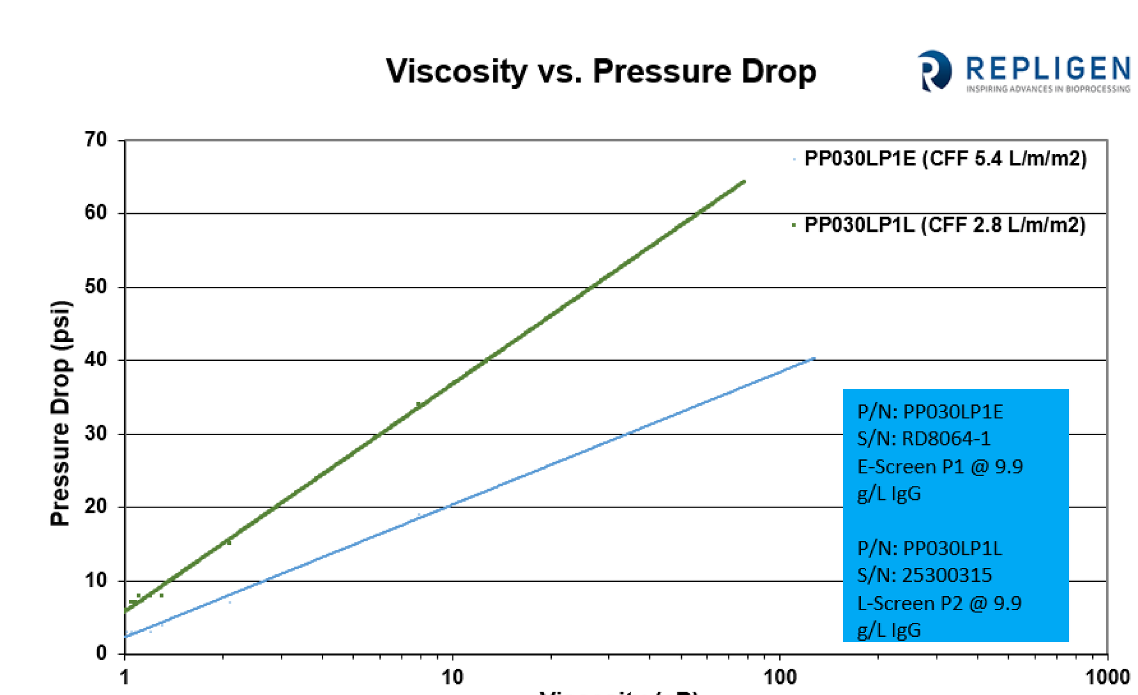
H-Channel: A tight screen channel (only offered with TangenX PRO Reusable Cassettes) used for low viscosity applications. Higher viscosity solutions are not optimal on this channel type as pressure drop is astronomically high. Typically generates the highest flux among its counterparts.

L-Channel: A thicker screen than the H-channel designed for slightly more viscous solutions (tightest screen offered for SIUS Product line). Generates good flux and acceptable pressure drop with solutions under 15cP.

E-Channel: A coarse screen with a lower pressure drop than the L and H Channel. Data supports the channel type as the most efficient with energy needed per unit volume of permeate.

S-Channel (Suspended Channel): A suspended screen with a lower pressure drop than E-channel. Designed to have low pressure drop while still having a turbulence promotor present. Performance acts similarly to J-Channel.

J-Channel (Open Channel): An open channel with no screen, designed to have a low pressure drop with high viscosities. Flux is very low compared to other channel types.



Conclusion

Each TangenX TFF cassettes are optimal for specific viscosities and applications within downstream processing. Selecting the 'best-fit' screen is crucial for optimizing the performance of UF/DF bioprocessing. Choosing a screen type with the operation parameters that maximizes the benefits of pressure drop and crossflow in conjunction with the viscosity of the feed stream, will enhance the efficiency of the TFF process. A screen that is too open or tight for the feed stream's viscosity will reduce the performance of the cassettes, driving operational cost up and reducing product recovery; therefore, determining the optimal screen for the feed stream is critical.

References

Chiranjit Bhattacharjee, V. K. Saxena & Suman Dutta (2019): Static turbulence promoters in cross-flow membrane filtration: a review, Chemical Engineering Communications, DOI: 10.1080/00986445.2019.1587610

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